ENCLOSURE 2

REPRESENTATIVE TASK ORDER (RTO)

Representative Task Order

Support for this RTO requires a level of understanding of a number of relevant scientific concepts and methodologies currently used to analyze cloud and precipitation data from the Global Precipitation Mission (GPM) core satellite and CloudSat, specifically the use of Ku-, Ka-, and W-band radar and microwave imager instruments. Relevant details are given in a number of papers and presentations that are included in the Procurement library database for the RFP.

Background

This RTO is for support of Government scientists performing research on a conceptual instrument, a *triple-frequency Doppler radar and microwave imager (TDRMI)*, for a future mission aimed at advancing the observation and characterization of clouds and precipitation. This instrument has been proposed by a team of cloud and precipitation experts from NASA Centers, NOAA, and the university community for a future cloud and precipitation mission as part of the Decadal Survey. For the purposes of this RTO, we are assuming HQ has accepted this as a Decadal Survey mission and has funded 610AT for the pre-launch design studies and post-launch support.

A TDRMI Science Team has been formed and includes AT members in the Mesoscale Atmospheric Processes Lab, the Climate and Radiation Lab, and the Wallops Field Station. It also includes participants from other areas of Goddard including GMAO, Hydrologic Sciences Lab, and the Goddard Earth Sciences Data and Information Services office. The TDRMI would combine scanning Ku, Ka, and W-band (13, 35 and 94 GHz) radars, with Doppler capability at all frequencies, with a passive microwave imager with channels covering 10-89, 118, 183-640 GHz, with V- and H-polarizations as appropriate.

This sensor suite should have sufficient spatial resolution to resolve convective scales at 1-5 km, allowing complete observation of all modes of precipitation from drizzle to deep convection and liquid and ice phase processes. To retrieve light shallow precipitation in particular, the radar system would need a high-sensitivity, fine range resolution capability. The inclusion of Doppler measurements to this observational platform affords a direct link between the storm dynamics and cloud microphysics. The inclusion of a passive microwave imager extends spatial coverage and provides information about surface characteristics necessary for rainfall retrievals. Motivated by the focus of the mission on cloud and precipitation processes, the emphasis of the observations is on quality (i.e., sensitivity, resolution, and Doppler accuracy) as opposed to quantity (i.e., swath width, multi-beam). However, a swath sufficient to capture the 3-D organization at the mesoscale (on the order of 100 km in horizontal length) is necessary to achieve the aforementioned quality of observations.

This RTO will support TDRMI research in two phases, pre-launch and post-launch. Pre-launch support under this RTO takes place over the first two years of the contract, while post-launch support takes place over the remaining three years of the contract. The time scale of required support is more compressed than we would expect a real mission to have, but the types of tasks are indicative of the types of actual work expected to be supported by the SAMDA contract.

General Requirements

Period of Performance:

Pre-Launch: Years 1 and 2

Post-Launch: Years 3 through 5

Location:

All work shall be performed at Goddard Space Flight Center (GSFC)

Meeting Requirements:

There will be one full Science Team meeting conducted annually and one algorithm development team meeting for the radar, imager, and combined radar-imager algorithms annually. At least one contractor scientist is expected to attend each of these meetings. Also, quarterly telecons are required for each of the algorithm development teams with at least one contractor scientist present at the telecons.

Deliverables:

Described with due dates in each of the sub-tasks described below.

Pre-Launch

Pre-Launch support involves algorithm development in preparation for launch, as well as trade studies to help in the instrumental design of TDRMI. It is assumed that Government will provide radiative transfer models and satellite simulators to compute TDRMI radiances as a function of surface, atmospheric, and cloud parameters in the satellite sensor field of view (FOV) on an orbiting satellite, as well as atmospheric composition datasets from GCM simulations and/or derived from satellite observations. A range of acceptable noise levels will also be provided for each channel. It is also assumed that the GPM core satellite and CloudSat instruments are still providing useful observations.

Results of research supported under this Task will be presented to the TDRMI Science Team at Science Team meetings and telecons. After approval by the TDRMI Science Team, improvements to the TDRMI retrieval methodology developed and validated under this Task will be implemented at the TDRMI Science Team Leader Computing Facility (TSTLCF) for use in extensive testing by the Science Team. The Science Team operational code will eventually be ported to the Goddard Data and Information Services Center (DISC) for the continuous operational processing of TDRMI radiance data and data products.

In support of the Government, the contractor shall do the following items:

1) *Develop and implement programs to generate proxy radiance and Doppler velocity data* for a set of case studies to be used in retrieval algorithm development. The TDRMI Science team will specify a representative set of case studies of different types of weather systems such as a tropical cyclone, a mid-latitude winter baroclinic cyclone, a warm season squall line, etc. For these cases, the sets of proxy channel radiances should be contained within the FOVs of each radar and channel of the microwave imager in TDRMI, and the Doppler velocity fields should be generated for the FOVs of the Doppler radars. The Government will provide programs to read GPM and CloudSat Level-1 radiances for the case studies, as well as radiative transfer codes to compute proxy radiance and Doppler velocity fields from the TDRMI sensors as a function of

surface and atmospheric parameters, such as surface emissivity, wind speed, and surface temperature.

Deliverable – The sets of proxy radiance and Doppler velocity fields for the ensemble of case studies shall be completed within 4 months after contract award.

2) *Modify existing relevant GPM and CloudSat retrieval programs*, to be provided by the Government, to read and use the TDRMI proxy radiance data as input to retrieval algorithms for the suite of cloud and precipitation products now available for GPM and CloudSat. The precipitation and cloud products such as cloud distributions, hydrometeor profiles, and precipitation rate and type retrieved from the proxy radiance data for the case studies should have a physical consistency on the same order as the same products retrieved from observed radiances from GPM and/or CloudSat for the case studies.

Deliverable – This requirement can be done concurrently with item #1. The report on the retrieval results and the modified codes shall be completed within 4 months after contract award.

3) *Optimize the retrieval methodologies* to take advantage of the particular combination of sensors and channels available on TDRMI, particularly the triple-frequency feature and Doppler capability of the radars, to improve upon the current suite of cloud and precipitation products. Starting at the current characteristics of the GPM (Ka and Ku, microwave imager) and CloudSat (W) sensors, the optimization should use the case studies to assess the accuracy of TDRMI-based retrievals with respect to:
    a. Adjusting noise levels
    b. Adjusting the sensitivity and range-resolution of the radars.
    c. Improving the spatial resolution of the microwave imager channels using 89 GHz from 5-km down to 1-km as the most important channel evaluation.
    d. Adding a multi-channel visible/infrared radiometer to the TDRMI to obtain additional information about cloud top and atmospheric properties.

    Synthetic products derived from instrument combinations and characteristics now available on GPM, called “GPM-like” products, will be compared to synthetic products using information uniquely from TDRMI: the W-band radar, a proposed Vis/IR radiometer, and/or the projected improved sensor characteristics of the TDRMI instruments. The TDRIMI unique products will be called “TDRMI products” and will be validated in an analogous manner to that currently being performed for GPM products. The Government will provide the validation programs and data currently used to validate GPM products.

Deliverable – The report and presentation of results will quantify the benefits to future cloud and precipitation retrievals from (1) the triple-frequency radar configuration, (2) the changes to instrument characteristics (a-c, above), (3) a proposed vis/IR radiometer (d, above). This requirement will completed within 1 year, starting 5 months after contract award.

4) *Conduct trade studies on validation experiments* needed to validate and improve TDRMI products post-launch. Validation of space-based datasets requires ground truth datasets from a variety of environmental conditions. The Government requires recommendations as to the types of observations that should be made or are already available, the environments or locations where they should be made, the mix of ground and sub-orbital instruments needed, and the best use of permanently installed instruments at Wallops to provide a temporally

continuous validation data stream. Supplementing these recommendation topics should be proposed error analysis strategies and appropriate metrics of retrieval accuracy and improvement developed from resources such as the published literature, experts in the field, and Science Team discussions. As recommendations develop, they will be presented to relevant algorithm teams within the TDRMI Science Team for comment and approval.

Deliverable – The validation trade studies will result in one or more reports that cover the required recommendations. Recommendations that are included in the reporting will have already been presented and preferably approved by the TDRMI Science Team. This requirement starts with #3 and will be completed and presented to the Government 12 months after contract award.

5) Aid in the preparation of 6 to 8 scientific reports, papers, and presentations annually to the TDRMI Science Team and scientific meetings.

6) Document all computer codes and the results of scientific experiments performed.

Deliverable – Tasks #5 and #6 will be on-going work that applies equally to both phases of the contract, and the deliverables are as requested by the Government.

Post-Launch

Post-Launch work centers on modification of Pre-Launch algorithms to reflect the reality of instrument performance in orbit, improving upon those algorithms, validating operational retrievals, and testing and implementing new products approved by the TDRMI Science Team. The TDRMI will use the results of the pre-launch validation trade studies to adopt a first-generation product validation strategy. The Government will provide the contractor with this validation strategy and relevant ground truth data. Improvements to the TDRMI retrieval methodology that have been approved by the TDRMI Science Team and new data products developed and validated under this Task will be implemented at the Goddard DISC for the continuous operational processing of TDRMI radiance data and data products. The results of research supported under this Task will be presented to the TDRMI Science Team at Science Team meetings and telecons.

In support of the Government, the contractor shall do the following items:

1) *Modify and validate the Pre-Launch retrieval algorithms* to account for differences in spectral and radiometric characteristics of the actual instruments from those assumed when generating the proxy radiance data sets. Modifications may also be required due to uncertainties in the radiative transfer physics used to generate the proxy data sets. If channels or entire sensors fail or perform sub-optimally after launch, alternative retrieval strategies will be explored. The validation work should follow strategies approved by the Science Team with all error analyses and performance metrics carefully performed and documented. The Government will supply observed radiance data, retrieval codes, and observed instrument characteristics.

Deliverable – A report on the validation results and the modified retrieval codes that use observed TDRMI data shall be generated no later than 6 months after receipt of observed data.

2) *Monitor, validate, and implement improved retrieval methodologies.* The monitoring of the quality (accuracy, timeliness, delivery format) of retrievals will follow the validation strategy

approved by the TDRMI Science Team and be on-going work post-launch. It will be accompanied by the validation and implementation of improved methodologies aimed at (a) processing efficiencies, (b) bias correction, (c) error reduction, (d) compensation for sensor data loss such as a failed channel, or (e) any combination of (a)-(d). After an improved retrieval methodology is approved by the TDRMI Science Team and successfully tested at the TSTLCF, the relevant radiance and validation data and retrieval codes will be supplied by the Government. The first part of the work is to verify that the retrieval results produced at the TSTLCF are scientifically equivalent to those produced at GSFC. Then there is a comparison of current operational products to products from the improved retrievals, followed by validation of the improved retrievals using the validation data supplied by the Government. During this work, contractor scientists should quantify whether the objectives of the retrieval have been met, or in the case of (d), to quantify any change in product quality due to data loss and substitution. If the retrieval objectives have been met, assistance will be provided to the Goddard DISC in implementing the improved retrieval codes into operational production.

Deliverable – #2 starts after modified retrievals are complete and continues to the end of the contract. One annual (year-end) report will be required on the quality control of all operational products from TDRMI. When an improved retrieval methodology is approved for validation and implementation at GSFC, the report on the validation results and modified retrieval codes will be generated no less than 4 months from the receipt of the new retrieval codes with implementation in no less than 6 months.

3) *Support the development of new data products* that could emerge from TDRMI radiance and Doppler velocity observations that are not currently offered by GPM or CloudSat. Products approved by the TDRMI Science Team are likely to be new cloud- and precipitation-related geophysical variables and parameters, but new products designed for oceanic, atmospheric, and surface variables/parameters may also arise. As design studies for new product development are typically supported by competed research (ROSES), this work involves the validation and implementation of proposed new products at GSFC after TDRMI Science Team approval and initial testing at the TSTLCF. The Government will furnish the relevant radiance data, validation data, and retrieval codes required to perform this work. The work flow will include modifications to the new retrieval codes required for efficient processing at the DISC and validation of the new products. However, validation of the new product may not be covered by the most current TDRMI Science Team validation strategy, and a new strategy with appropriate error analyses may have to be developed in consultation with the Science Team. The objective of #3 is for the new product produced at the DISC to achieve the scientific accuracy determined by the TDRMI Science Team for that variable/parameter.

Deliverable – This work starts no less than 1 year after launch and continues to the end of the contract. When a new product retrieval methodology is approved for testing at GSFC, the report on the validation results and modified retrieval codes will be generated no less than 4 months from the receipt of the new retrieval codes with implementation in no less than 6 months.

NOTE: The Pre-Launch phase tasks #5 and #6 also apply to this phase with the same objectives and deliverables.